stratasys
DIRECT MANUFACTURING

ADVANCED MANUFACTURING SERVICES

ADDITIVE METAL

GENSETS Kickoff Meeting

Andrew Carter | Manufacturing/Process Engineer

Oct. 21, 2015

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Who We Are

Technologies & Services

Additive Metals

How Rapid Manufacturing Can Help You

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About Stratasys Direct Manufacturing

Stratasys Direct Manufacturing is one of the largest providers of additive and conventional manufacturing solutions:

- 8 U.S. manufacturing facilities
- 12 manufacturing technologies
- 600+ employees
- Certifications: ISO 9001, AS9100
- ITAR registered

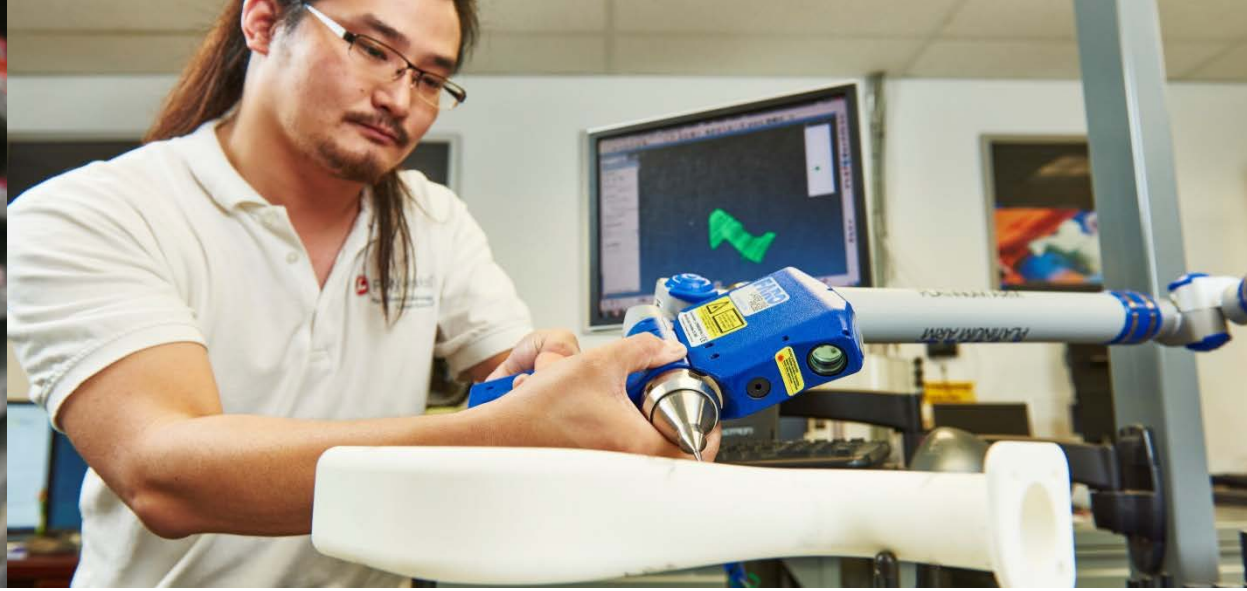
Manufacturing Facilities

- Valencia, CA
- Poway, CA
- Tucson, AZ
- Phoenix, AZ
- Eden Prairie, MN
- Austin, TX
- Belton, TX
- Troy, MI

Your Team

Our experienced team of project engineers is committed to your success with:

- Design support for advanced manufacturing
- Technical direction and recommendations
- Material, technology and build optimization for quality, speed and reduced cost



Quality Systems

We are committed to providing high quality parts and prototypes. Each part undergoes quality inspections during the incoming, in-process and final production. We have the ability to test both destructively and non-destructively, as well as the ability to perform AS9102 FAI's utilizing CMM technology.

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Additive Metals At Stratasys Direct

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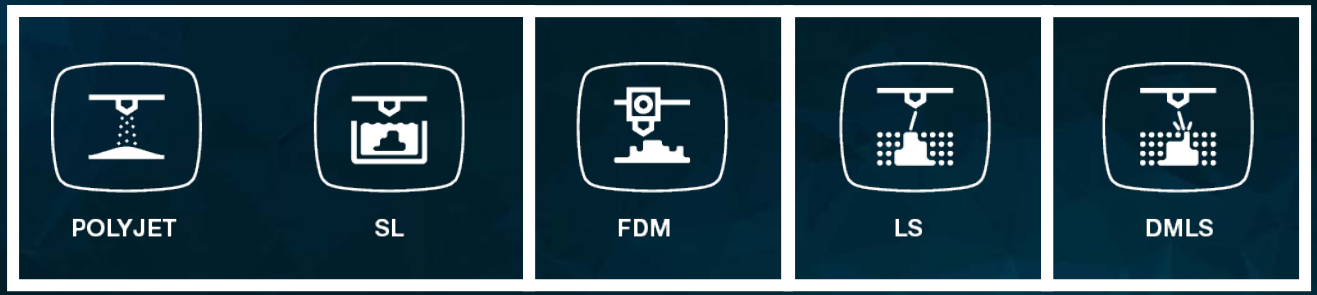
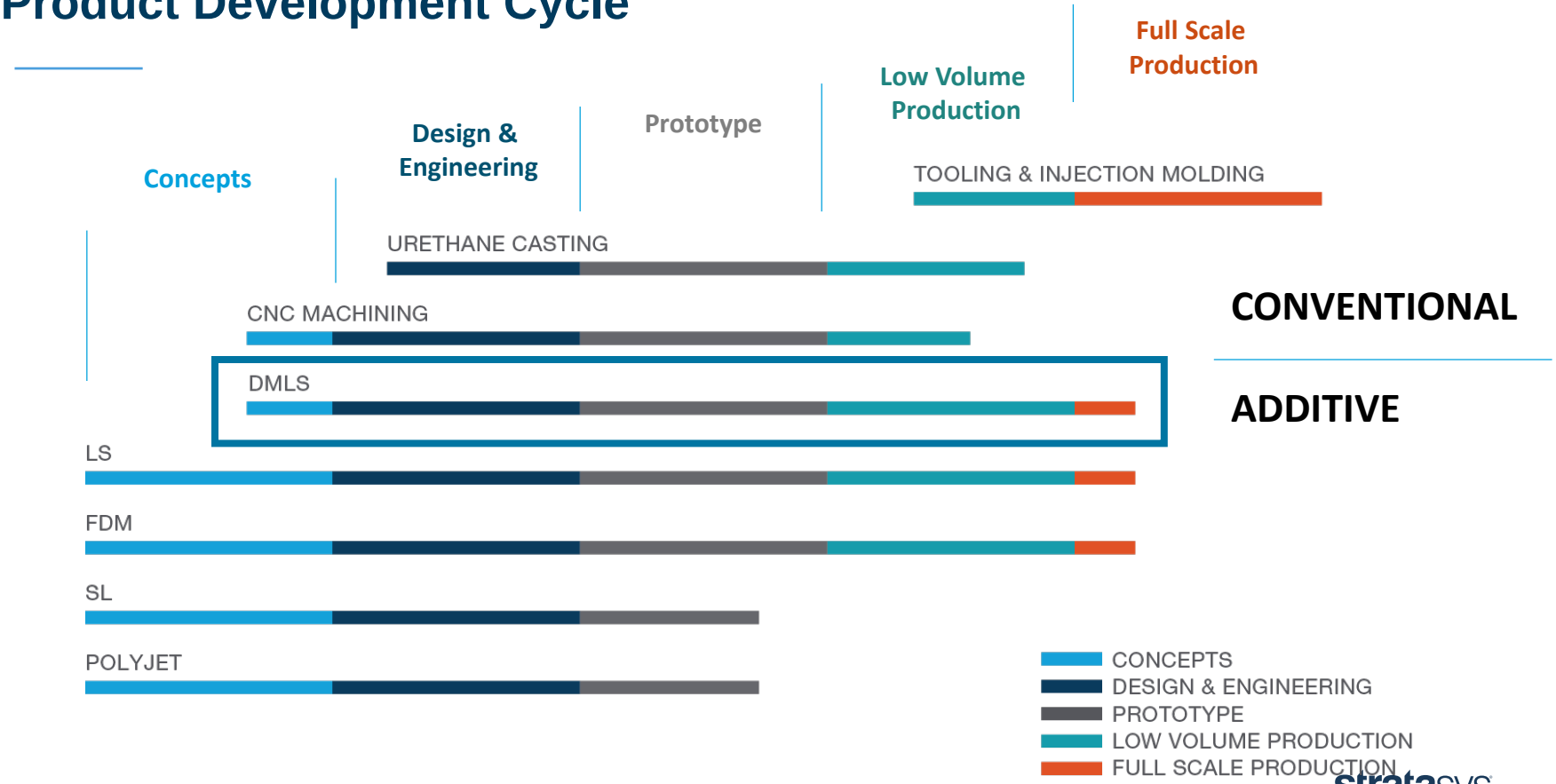
Technologies

ADDITIVE



CONVENTIONAL

Product Development Cycle



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Laser Based Metal Powder Bed Fusion

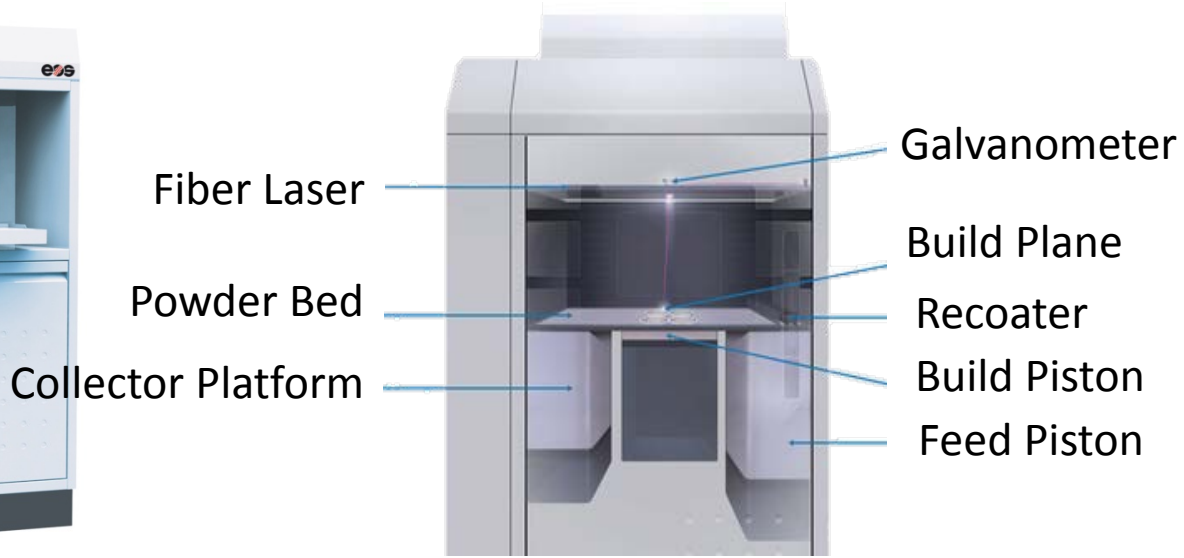
An **additive** process.

It builds parts by consecutively distributing fine **layers of powder** metal and **selectively melting regions** defined by a 2D slice of a 3D CAD model.

- Laser Based Powder Bed Fusion Processes:
  - *Direct Metal Laser Sintering, DMLS* - EOS
  - *LaserCusing* - Concept Laser
  - *Selective Laser Melting* - SLM

DMLS M280 Platform.

250X250X280mm Build Volume ● 400W Fiber Laser ● N or Ar – Environment
Builds with 20µm to 100 µm layers ● Smallest Features = 0.012”
Smallest Hole Diameter = 0.035” ● Standard Tolerance = ± 0.005”
Deposition rates of = 1in^3 per 2.5hrs



Stratasys Direct Manufacturing Machine Fleet and Department Structure

Two Facilities located in: *Austin, TX* and *Belton, TX*

Fourteen Laser Based Metal Powder Bed Machines.

8 M280's & 1 M270 in Austin, TX

4 M280's and 1 M290 in Belton, TX

Eight Different Materials

Department Positions

Programmers, Finishers, Machinist, Technician, Application & Manufacturing Engineers.

Post AMM Support

CNC Mill, CNC Lathe, Wire EDM, Wire Drill, 3 axis mill, lathe, surface grinder, Stress-relief kiln, down draft tables, and shot peen blast cabinets

Inspection Equipment

Metallographic Polisher & Microscope, Profilometer, CMM.

X-ray, CT scan, FPI, SEM, Mechanical Testing

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DMLS Applications

- Complex turbine components
- Conformal cooling channels
- High-temperature housings
- Complex tools/instruments
- Medical and dental implants

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Additive Alloys

Feedstock = Argon gas atomized powder.

Current Offering

SS 17-4 PH*, SS316L

IN 625*, IN 718*,
IN718 API-std, CoCr

AlSi10Mg, Ti 6-4 Gd5*,

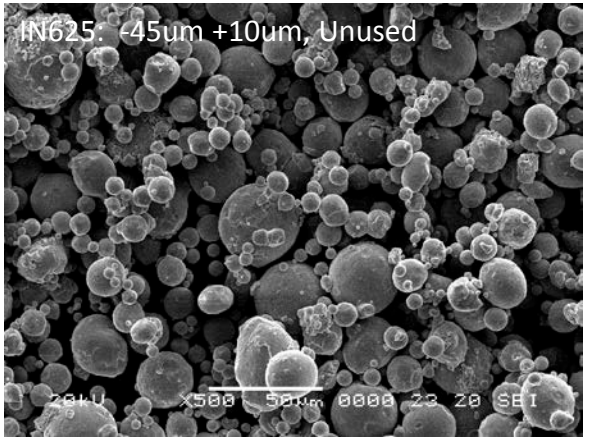
Material Process Development

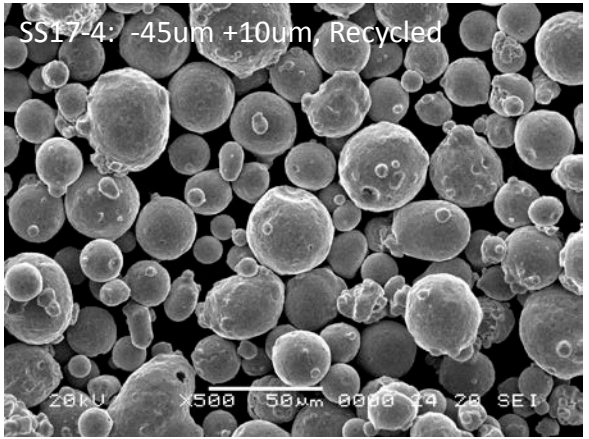
Al6061, Monel K500,

Invar36, IN939, C18150

Powder chemistry ordered to meet respective AMS standards.

Projects slated for Q4 2015





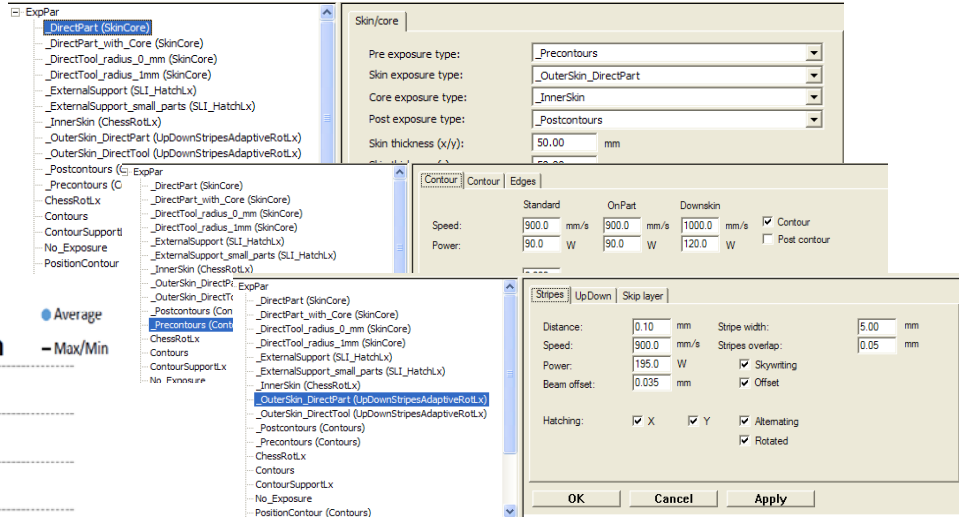
Process Optimization

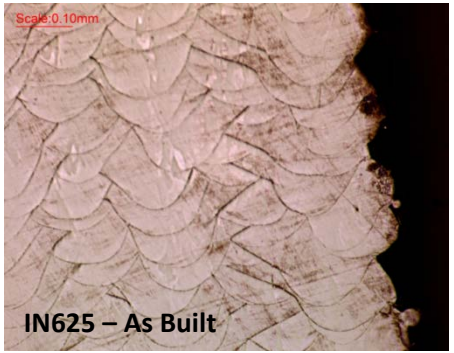
EOS Parameter Editor

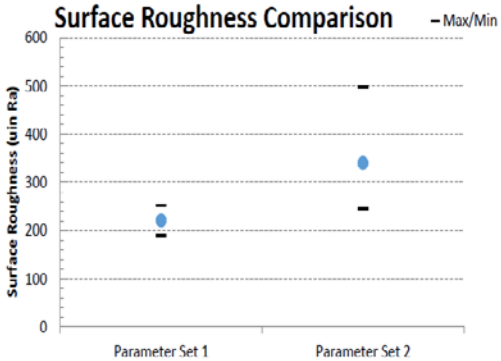
Opens up over 100 laser, scan, and machine settings.

Proprietary Scan Settings developed in house.

Developed for maximum density, improved surface finish, & reduced build time.







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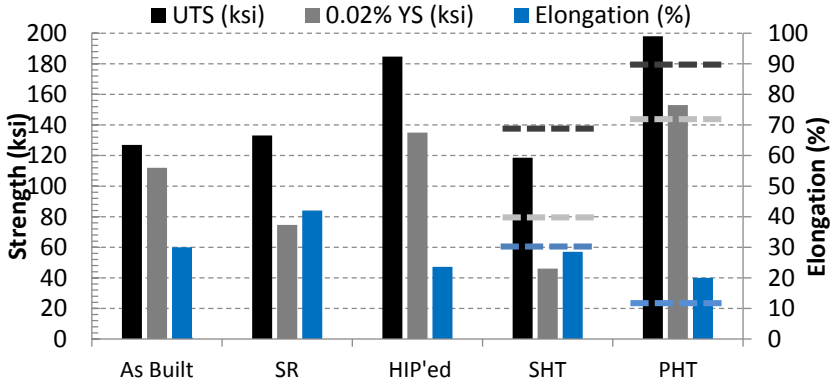
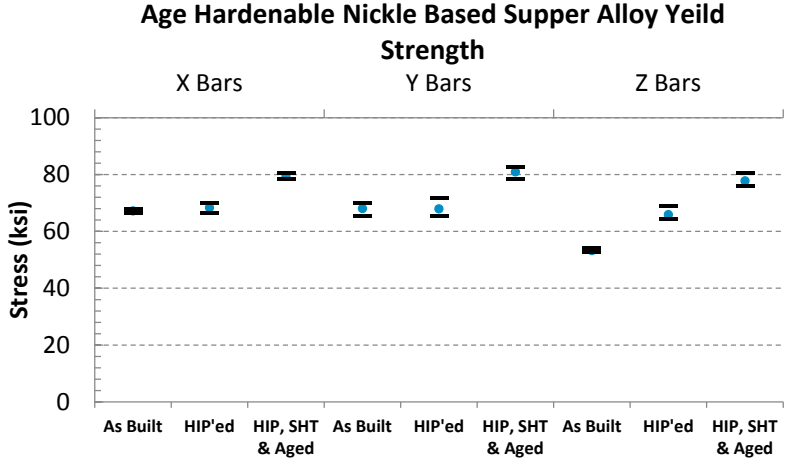
Material Properties

Tensile properties are near equivalent to **conventional wrought** properties.

Homogized mechanical properties following heat treatments.

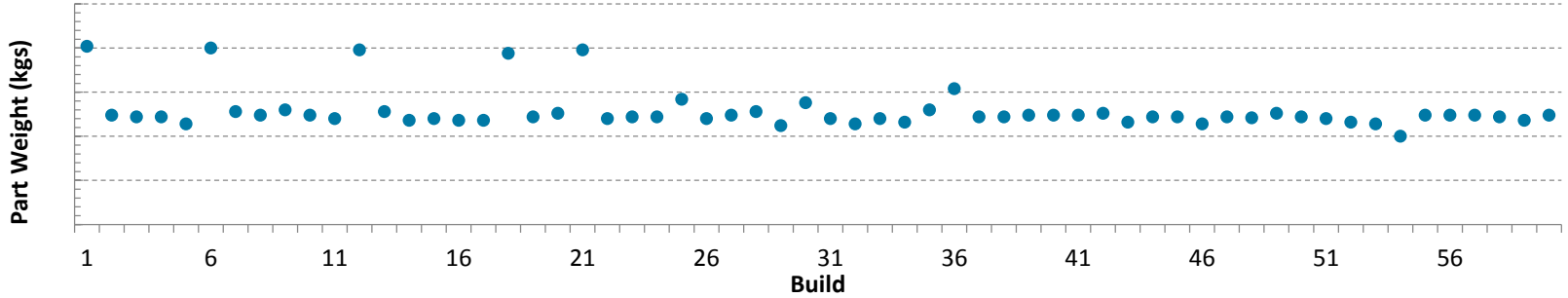
Material density is ~**99.5%**
(or 0.5% porous)



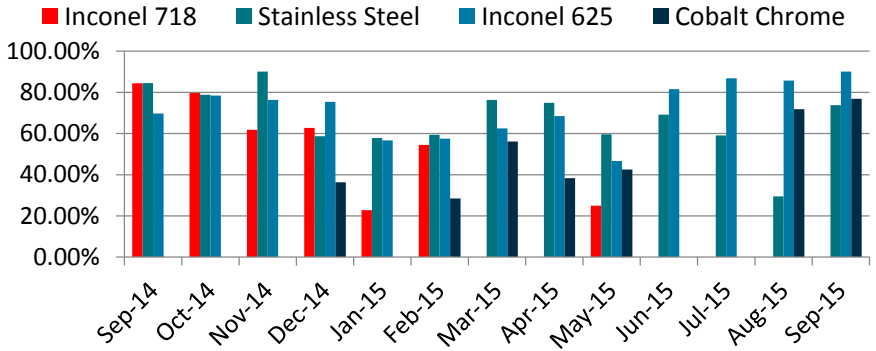


Process Control & Performance Metrics

Part and Power Weight out of Machine



DMLS Material Utilization

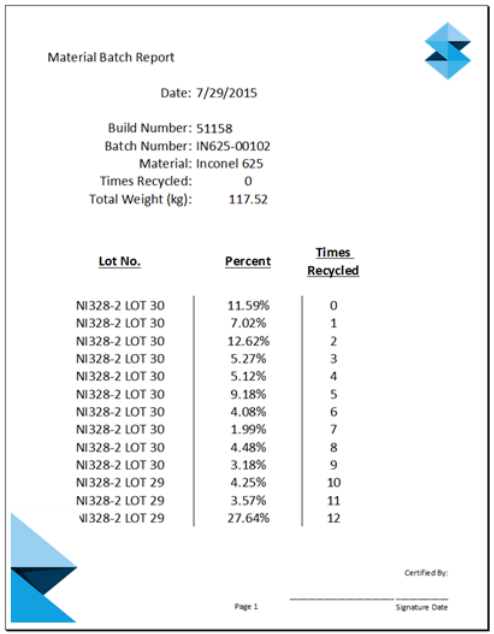


Track material usage and identify unnecessary waste.

Track material utilization for production machines.

Material Composition and Degradation

- *Addressing the industry wide question.*



Material Batch Report

Date: 7/29/2015

Build Number: 51158
Batch Number: IN625-00102
Material: Inconel 625
Times Recycled: 0
Total Weight (kg): 117.52

Lot No.	Percent	Times Recycled
NI328-2 LOT 30	11.59%	0
NI328-2 LOT 30	7.02%	1
NI328-2 LOT 30	12.62%	2
NI328-2 LOT 30	5.27%	3
NI328-2 LOT 30	5.12%	4
NI328-2 LOT 30	9.18%	5
NI328-2 LOT 30	4.08%	6
NI328-2 LOT 30	1.99%	7
NI328-2 LOT 30	4.48%	8
NI328-2 LOT 30	3.18%	9
NI328-2 LOT 29	4.25%	10
NI328-2 LOT 29	3.57%	11
NI328-2 LOT 29	27.64%	12

Certified By:

Page 1

Signature Date

Material Property Study - Insight into Powder Life Cycle

Tensile and Microstructure

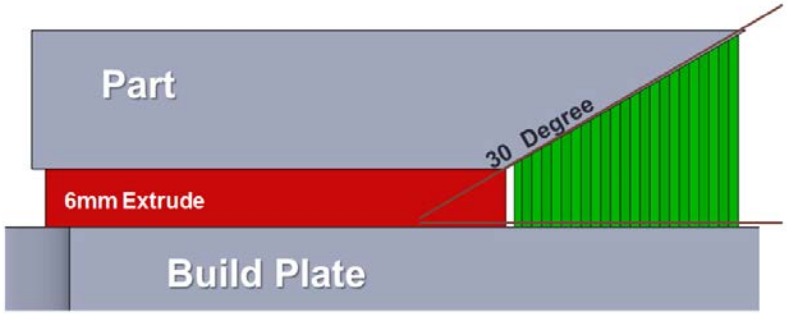
Industry claims powder degrades with time and exposure.
Companies are forming around the fear
Customer's specs call for no part to be built with any powder older than 90 days.

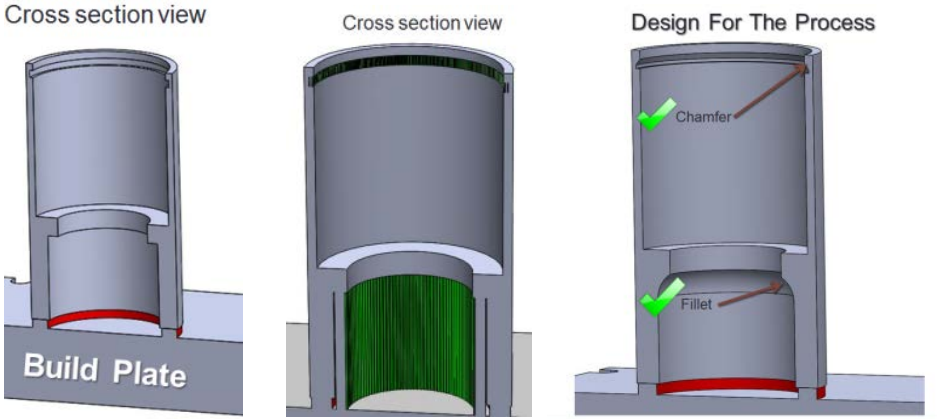
SDM's answer:
- 7 machines building the same material undergoing the same material refresh rate
- 2 tensile bars and 1 metallographic coupon positioned per plate
- over 40 builds/machine

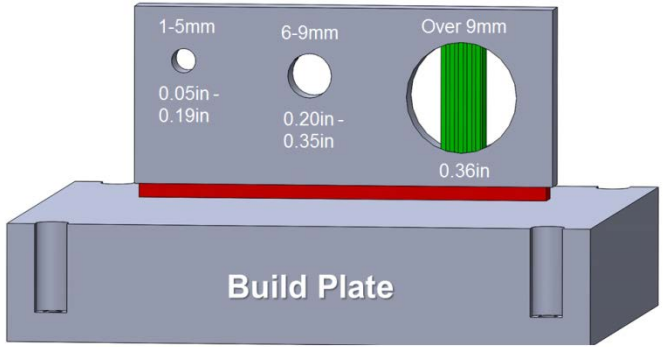
Material properties trended against **Blend Composition** will answer industry's question of powder degradation.

Design Guidelines – General Rules of Thumb

- Angled Surfaces
  - *<30deg surfaces will requires supports*
- Horizontal Holes
  - *1-5 mm will build fairly uniform*
  - *6-9mm will be out of round*
  - *>9mm will requires support structures.*
- Eliminate Trapped Supports
  - *Include fillets and chamfers when possible.*







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Added Additive Benefit

- Part/assembly consolidation
- Supply chain management
- Design freedom & Design iteration
- Manufacturing lead time savings
- Performance improvements

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Offer a Variety of High Temperature Super Alloys

Alloy	Melt Temp	Ultimate Tensile Strength (ksi)	Recommended Heat Treatments*	Wear-Resistance, Corrosion Resistance
IN625	1350°C/2460°F	128	SR, HIP, SHT	High
IN718	1280°C/2336°F	198	SR, HIP, SHT, PHT	High
CoCr	1500°C/2730°F	140	SR, HIP, SHT, PHT	High

*SR = Stress Relief, HIP = Hot Isostatic Press, SHT = Solution Heat Treat, PHT = Precipitation Heat Treat

An experienced application development team

"Implementation of Direct Metal Laser sintering to Manufacture Advanced Combustion Liners with Shaped Film Cooling Holes for Gas Turbine Engines" Contract No. W911W614-C-0015

EXAMPLE: Honeywell Aerospace SHF Engine
http://www.flightglobal.com/news/articles/honeywell39s-demonstrator-shfe-engine-set-for-testing-212326/

"Implementation of Direct Metal Laser Sintering to Manufacture Monel K500 Liquid Rocket Engine Components" Contract No. FA9300-14-M-1006

EXAMPLE: Aerojet Rocketdyne HCB demonstrator
http://www.rocket.com/hydrocarbon-boost-hcb

Do you have a specific alloy in mind?

Stratasys Direct will diversify material portfolio for their customers.

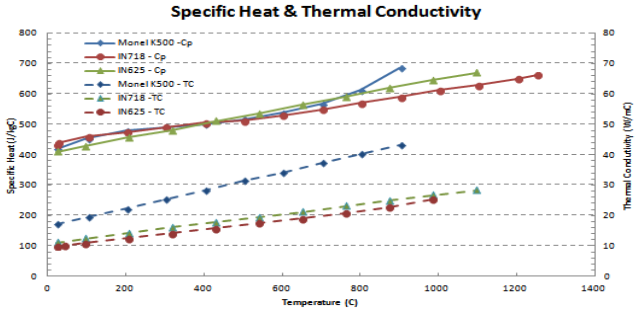
Duration: A 2 Phase, 4 - 5 Months ;

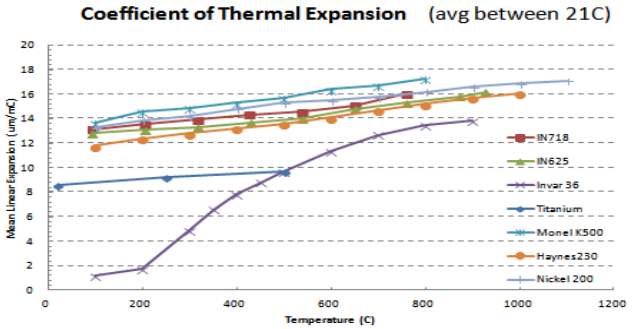
Phase 1:

1.1 Procure 100kgs of Ar gas atomized powder +15um-45um powder.
1.2 Powder and Chemical Characterization
(pre and post build)
1.3 Initial Energy Flux DOE

Phase 2:

2.1 Surface roughness DOE
2.2 Powder Degradation Study *(5 to 10 consecutive build study)*
2.3 Mechanical Coupons *(tensile, impact, fatigue)*
2.4 Thermal Condition Study *(mechanical, metallographic)*





Active Programs: Monel K500, Al6061 - **Funded Programs:** Invar 36, C18150

SDM Differentiating Points to Remember

SDM's **25 years experience** originates in **Rapid Prototyping** and **Rapid Manufacturing** in **Additive Processes** including: *SL, LS, FDM, PolyJet.*

SDM **separates** our business from the competition by relying and applying this material and process knowledge to **laser based metal powder bed fusion** process.

STRATASYS IS THE TRUSTED LEADER IN INNOVATIVE 3D PRINTING AND MANUFACTURING SOLUTIONS THAT EMPOWER INDIVIDUALS AND ORGANIZATIONS TO TRANSFORM THE WAY THEY IMAGINE, DESIGN AND MAKE THINGS.